Measuring Dark Energy with Gravitational Lensing in the Dark Energy Survey

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My Involvement in BNL Projects

- Dark Energy Survey (DES), co-leading development of lensing pipelines and analysis codes to measure Dark Energy. $w = p/\rho$

- Baryon Oscillation Spectroscopic Survey (BOSS), leading the spectroscopic target selection. Primary goal measurement of Dark Energy properties

- Working on early development of Large Synoptic Survey Telescope (LSST) lensing pipelines

DES: Cerro Tololo International Observatory, Chile

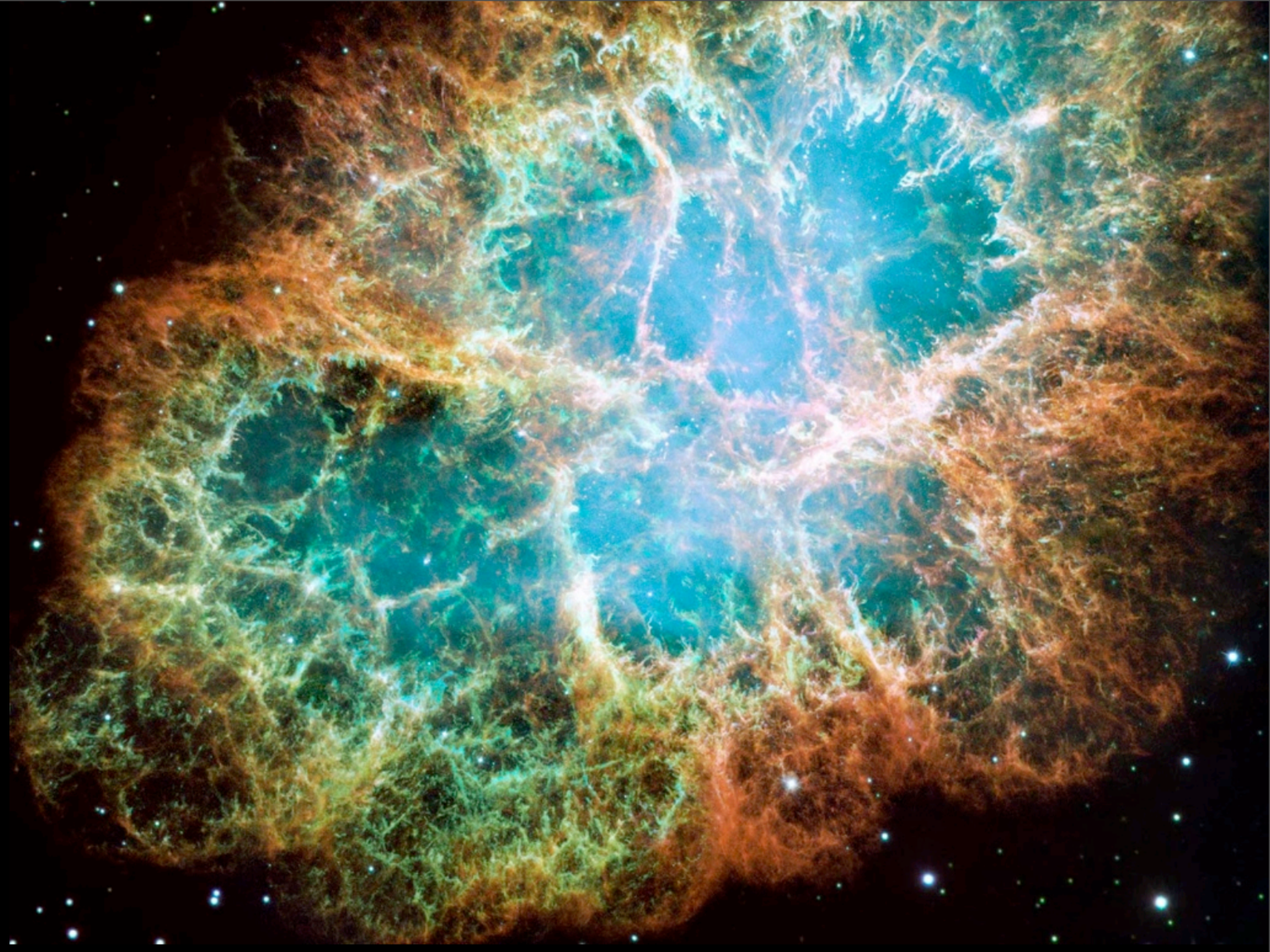
Blanco Telescope

Image: David Walker

Dark Energy Survey

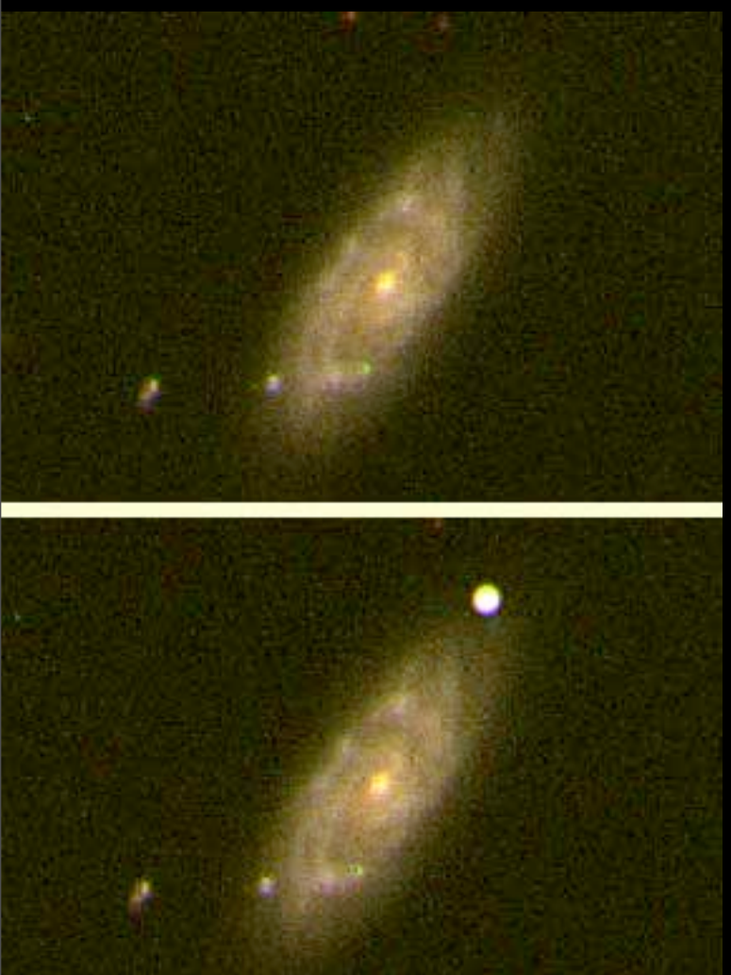
- Optical survey of 5000 square degrees in multiple bandpasses.
- 4 meter "Blanco" telescope at Cerro Tololo Inter-American Observatory, Chile.
- First light Winter 2011, running 5 years
- Measure equation of state parameter to 3% using a variety of techniques
- Camera and Telescope upgrades DOE funded

Dark Energy



Crab Nebula supernova remnant, Hubble Space Telescope

Supernova Cosmology Project



Dark Energy was discovered by examining the relative brightnesses of supernovae as a function of cosmic time

Effects of Dark Energy

- At early times is unimportant to the expansion rate and growth of massive structures
- At late times accelerates the expansion rate, dramatically increasing volume
- Decreases the overall "growth rate" of massive structures.
- Number density of massive structures is decreased relative to equivalent matter only universe

Clusters of Galaxies

Coma Cluster
SDSS Imaging

1.3 Mpc across
1pc = 3.3 lyr

Number Density of Galaxy Clusters

- In the early universe clusters form normally
- At late times Dark Energy accelerates the expansion, reducing the number density relative to a matter-only universe
- Number density of clusters with given mass is sensitive to Dark Energy

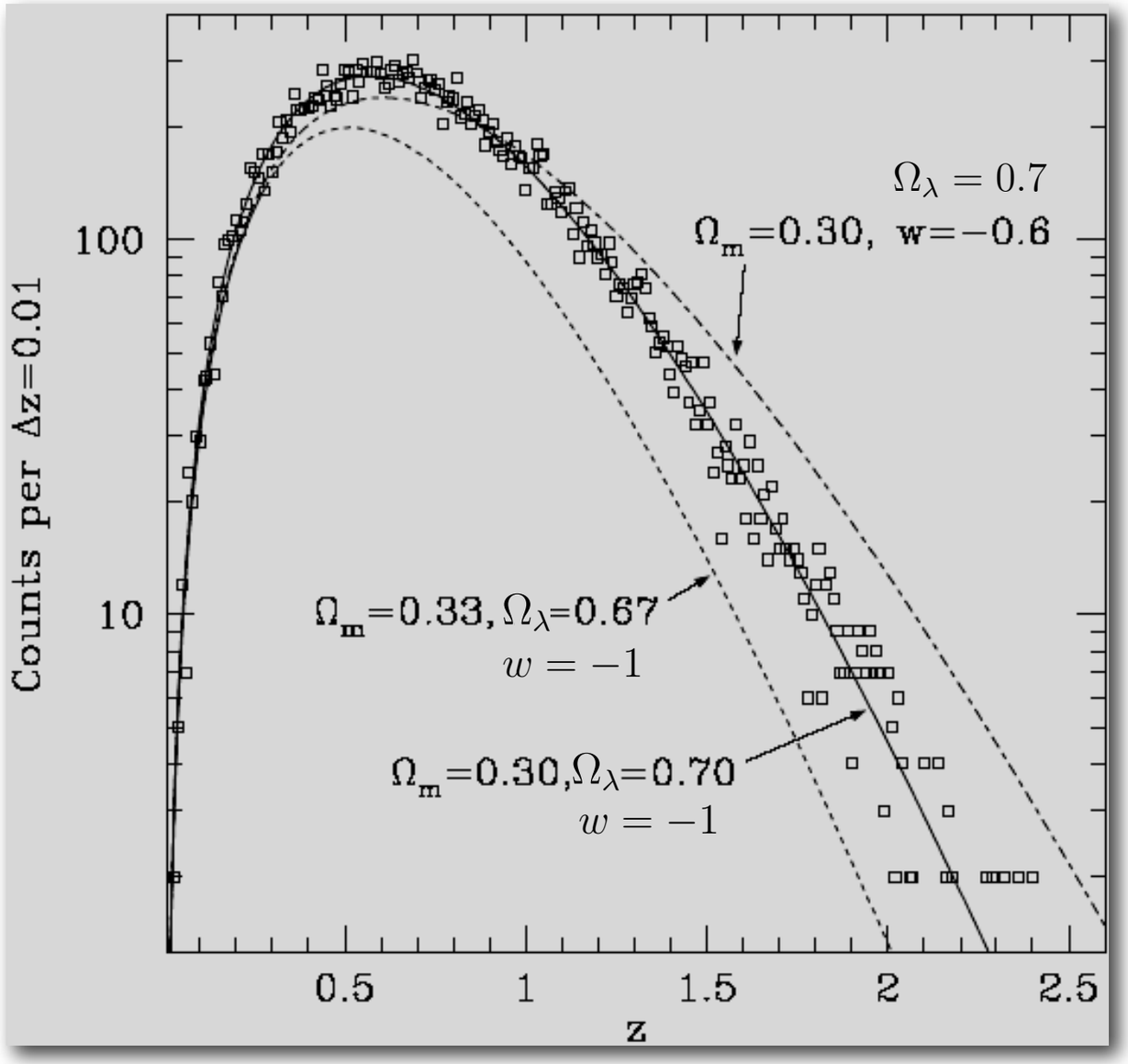
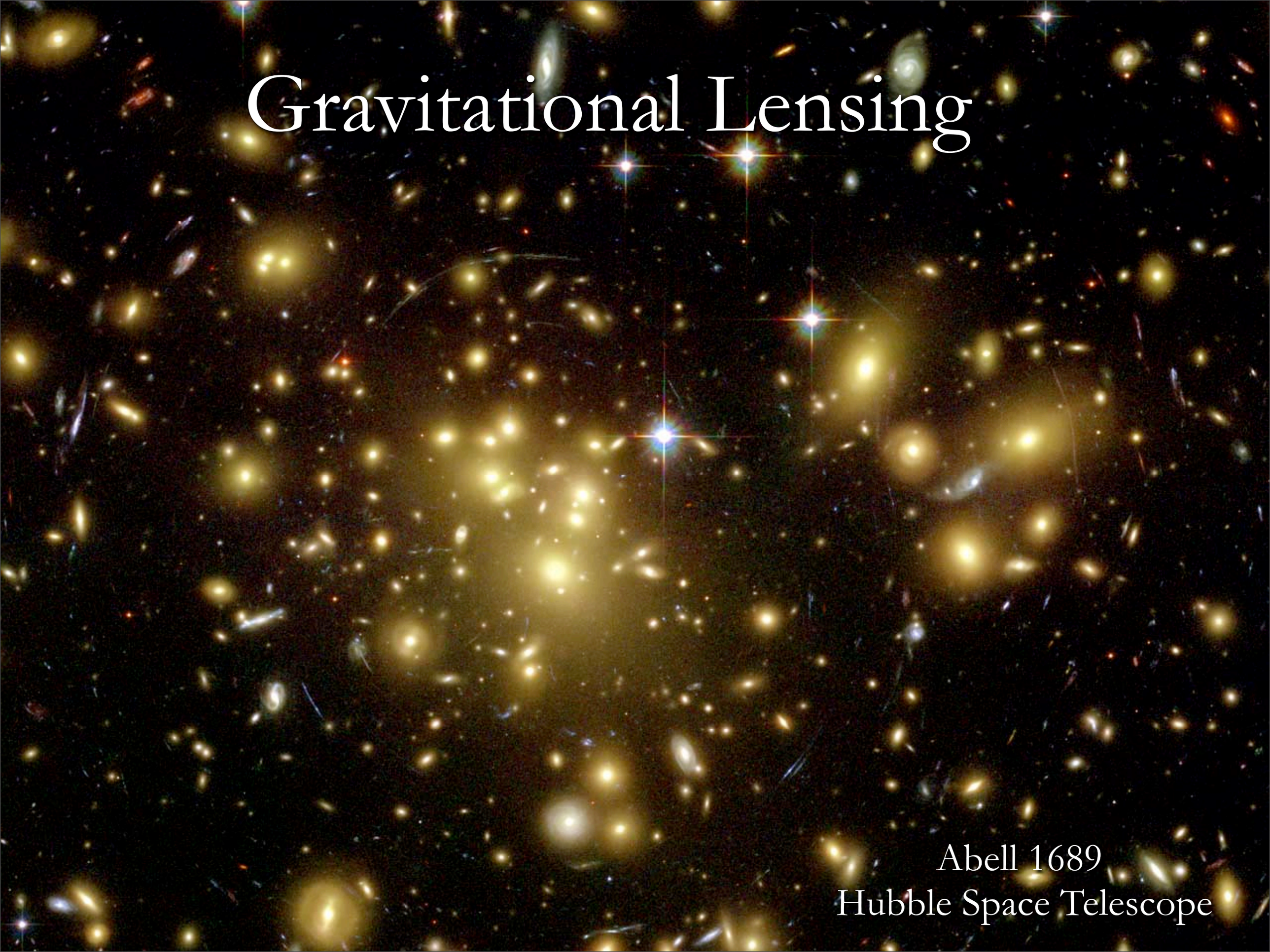


Image Courtesy SPT

Gravitational Lensing



Abell 1689
Hubble Space Telescope

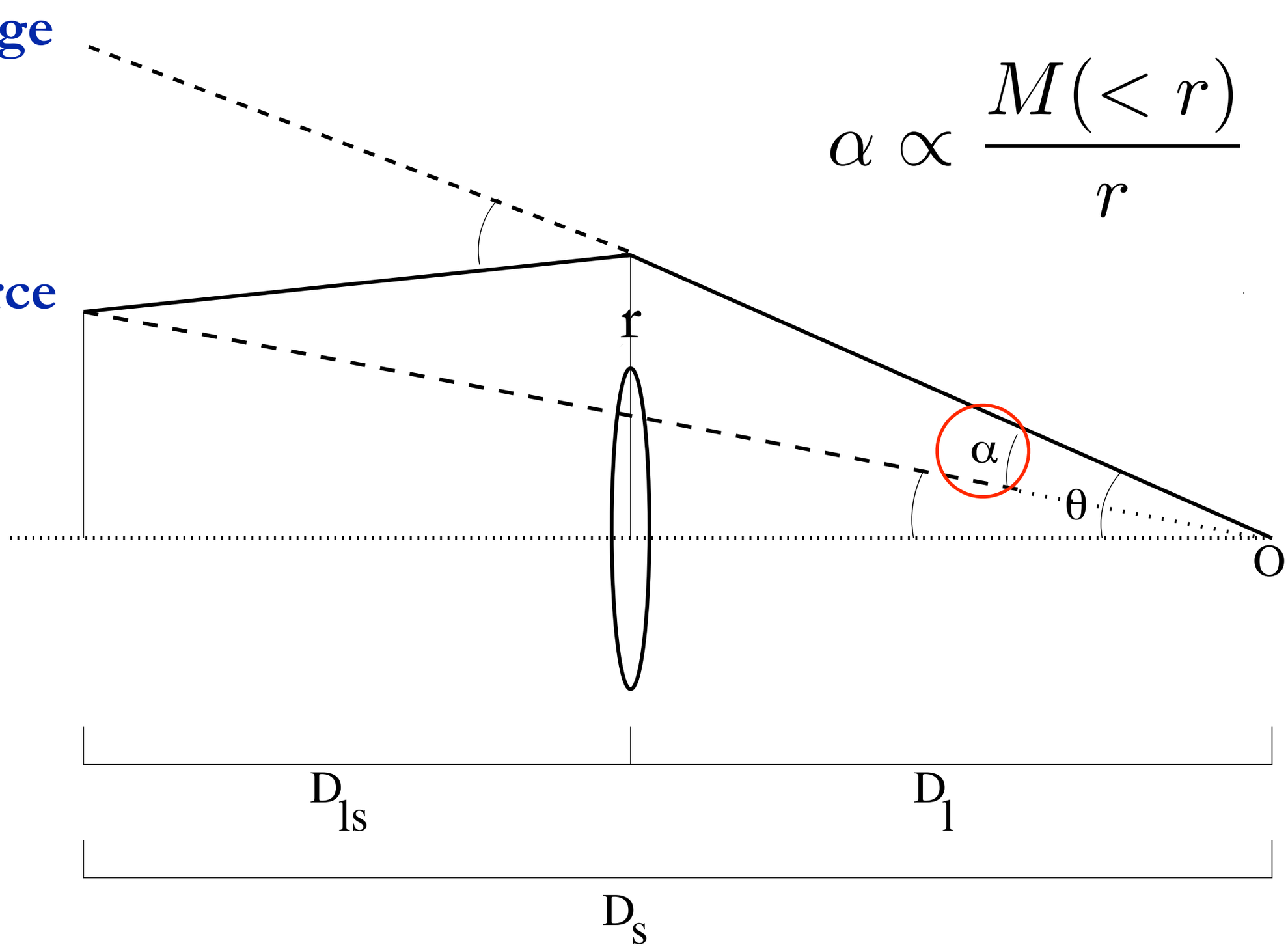
Galaxy Cluster Abell 1689 Details

Hubble Space Telescope • Advanced Camera for Surveys

NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin(STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA • STScI-PRC03-01b

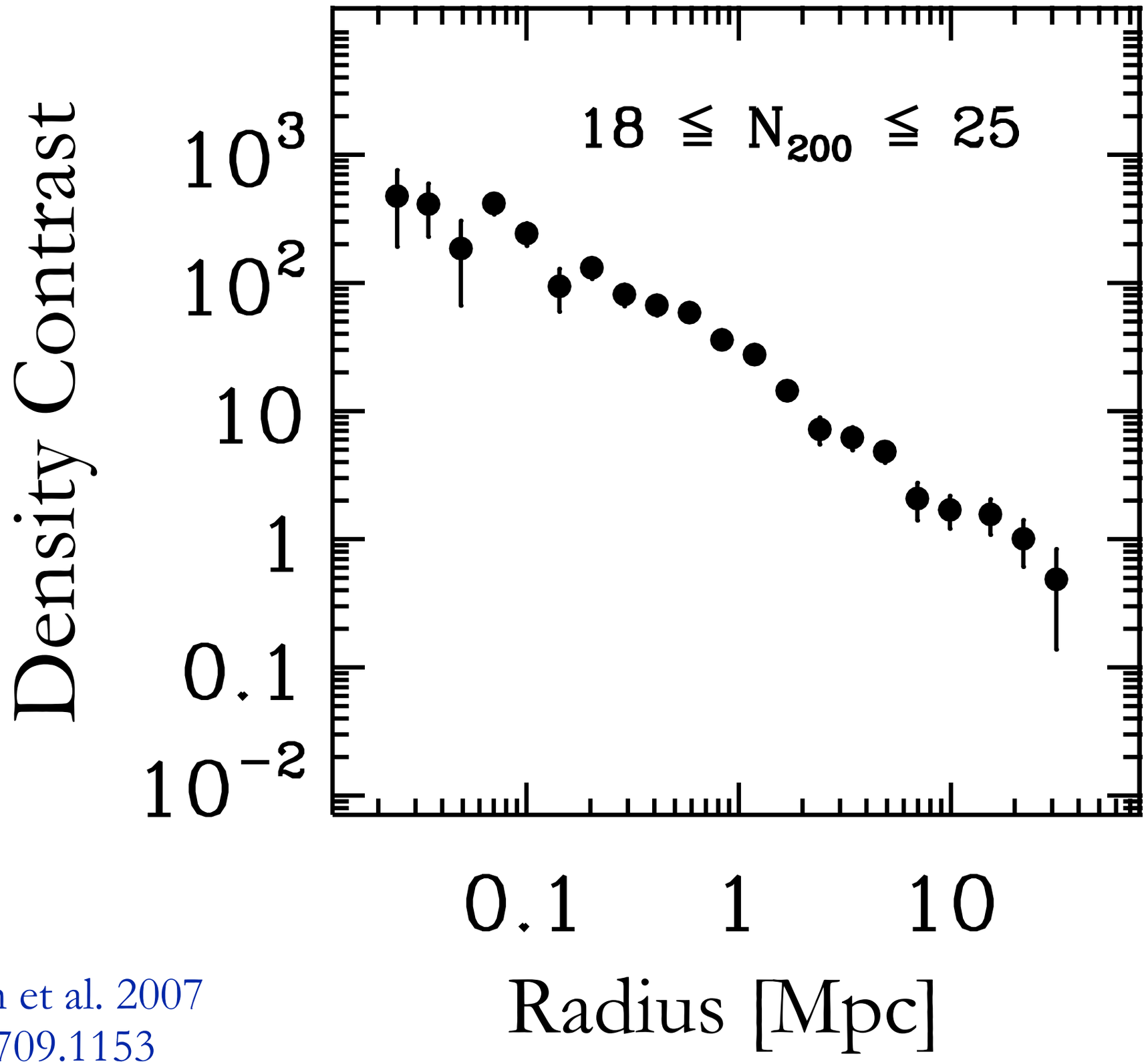
Gravitational Lensing

$$\alpha \propto \frac{M(<r)}{r}$$



Whirlpool Galaxy
SDSS Imaging

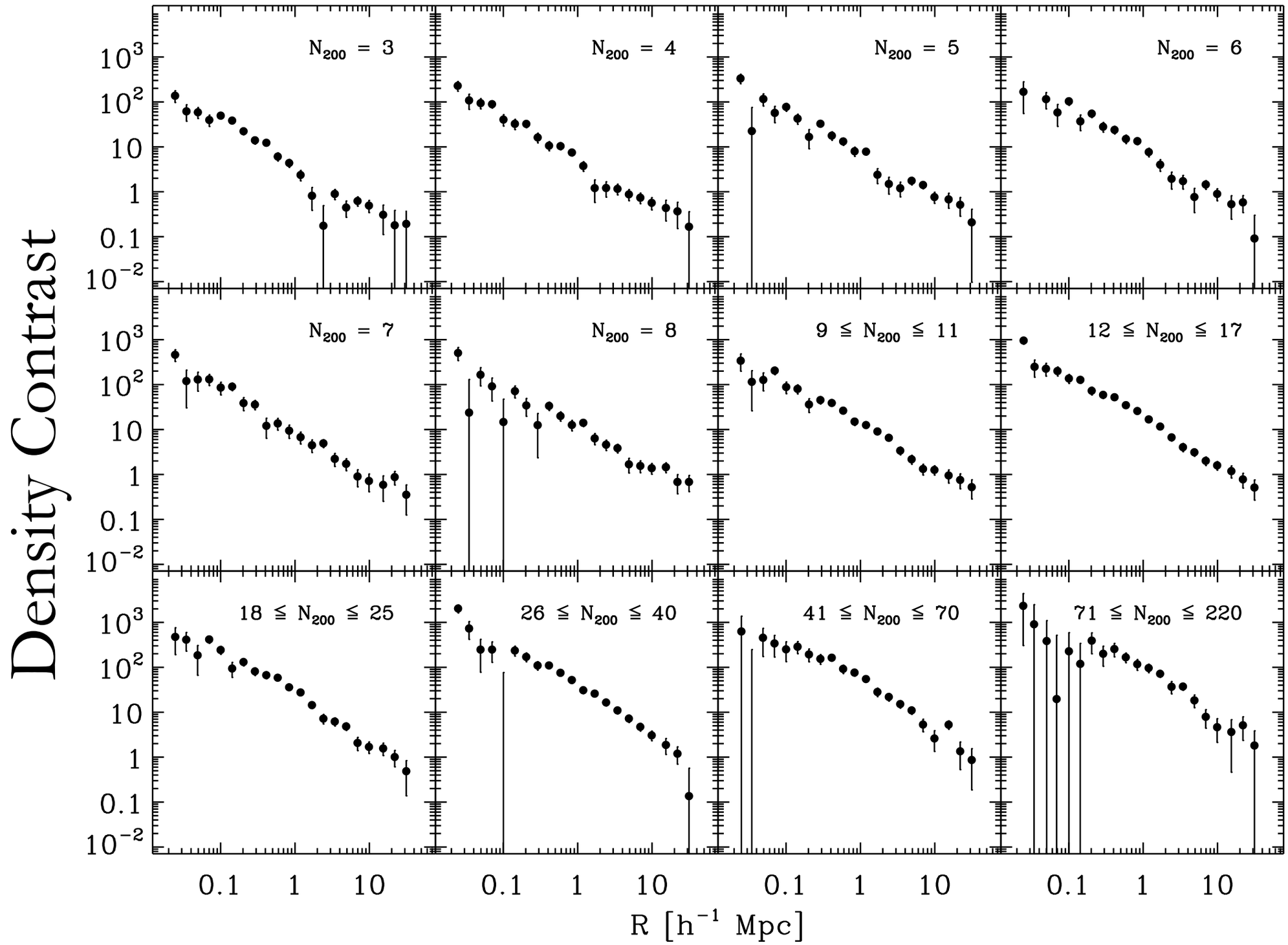
The Typical Lensing Effect is Tiny



Sheldon et al. 2007
arXiv:0709.1153

1pc = 3.26 lyr

Bin by the number of galaxies in the cluster



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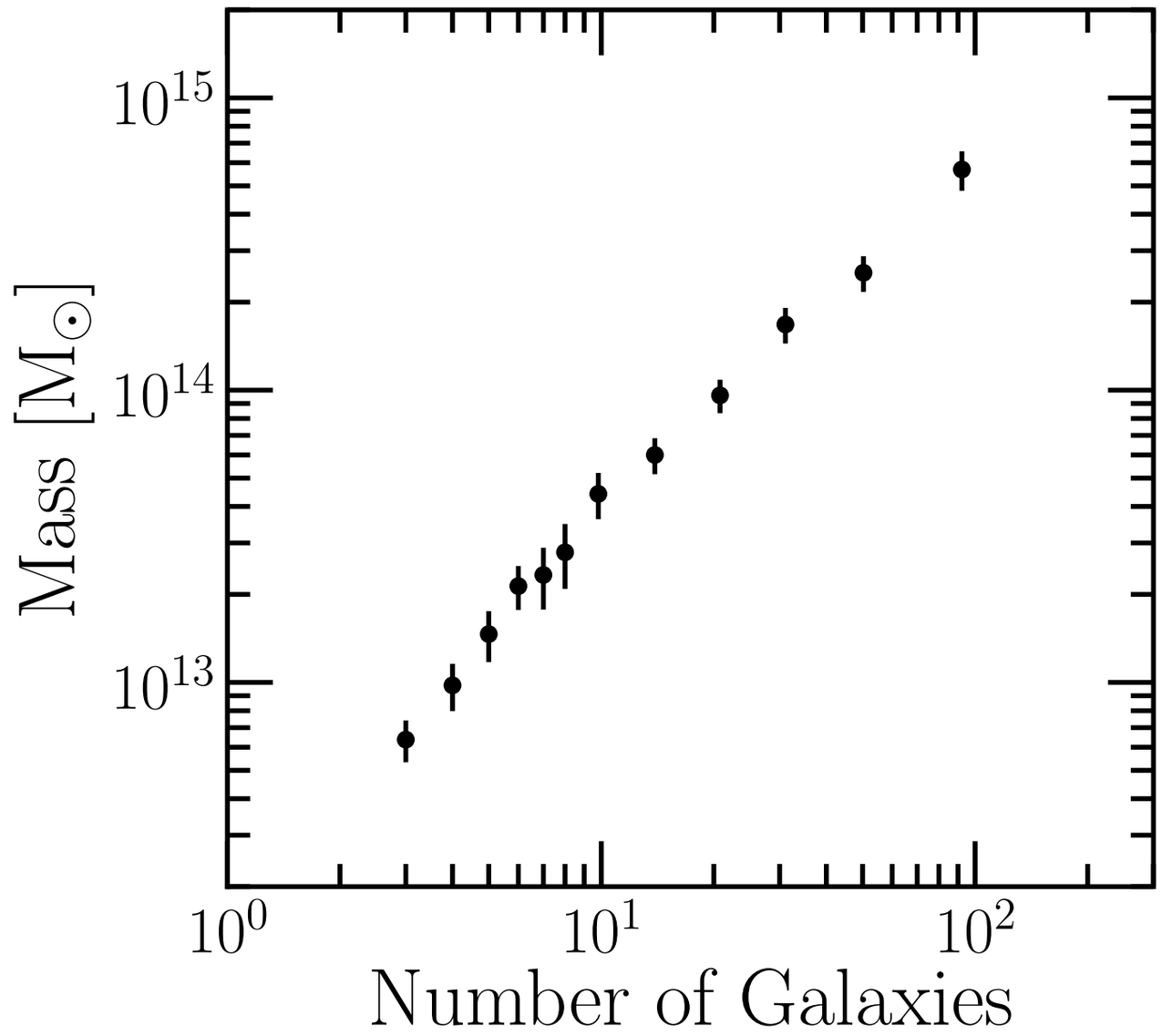
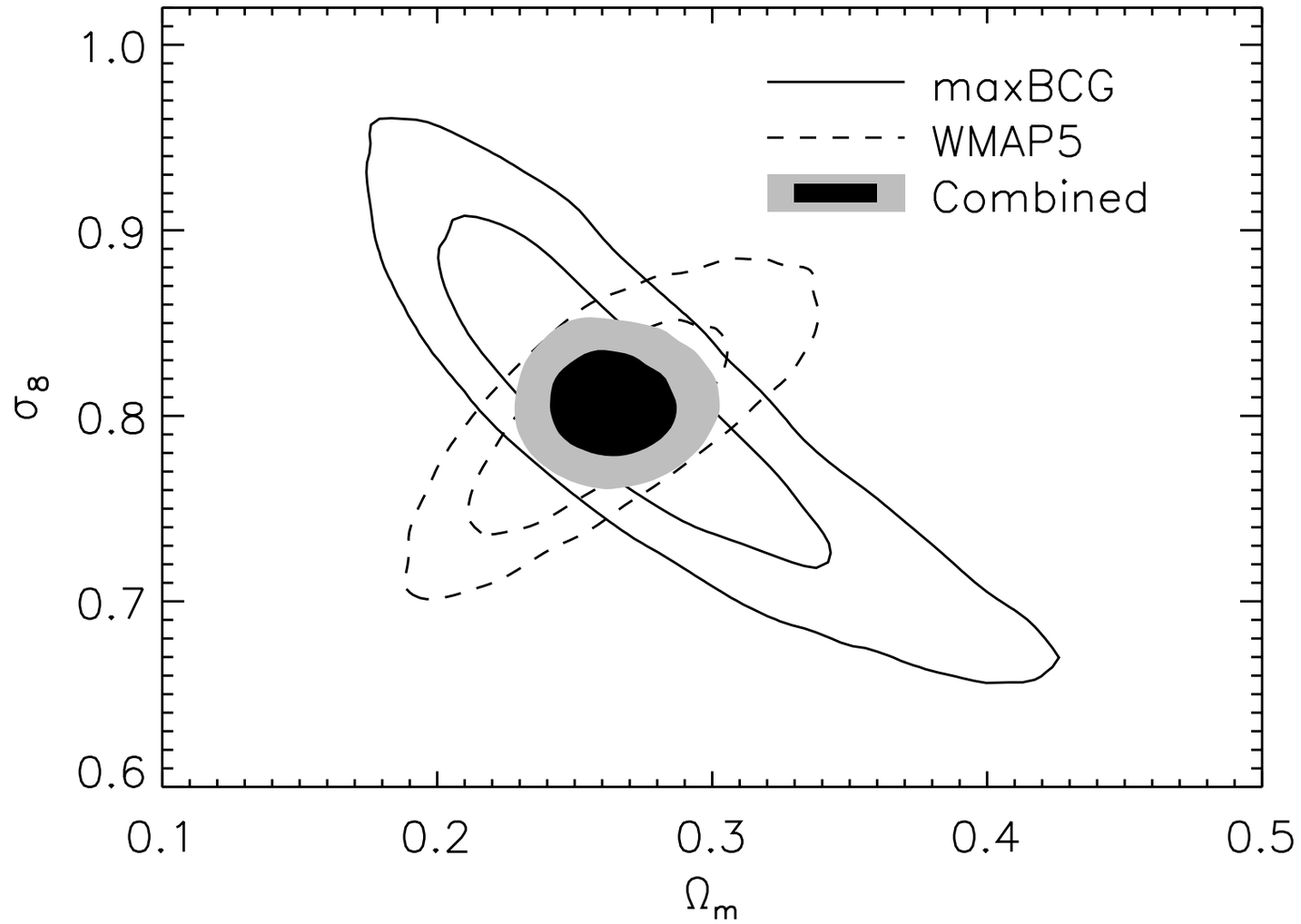
SDSS Cluster Lensing

Using existing analysis techniques we can measure the relationship between cluster observables and the total mass



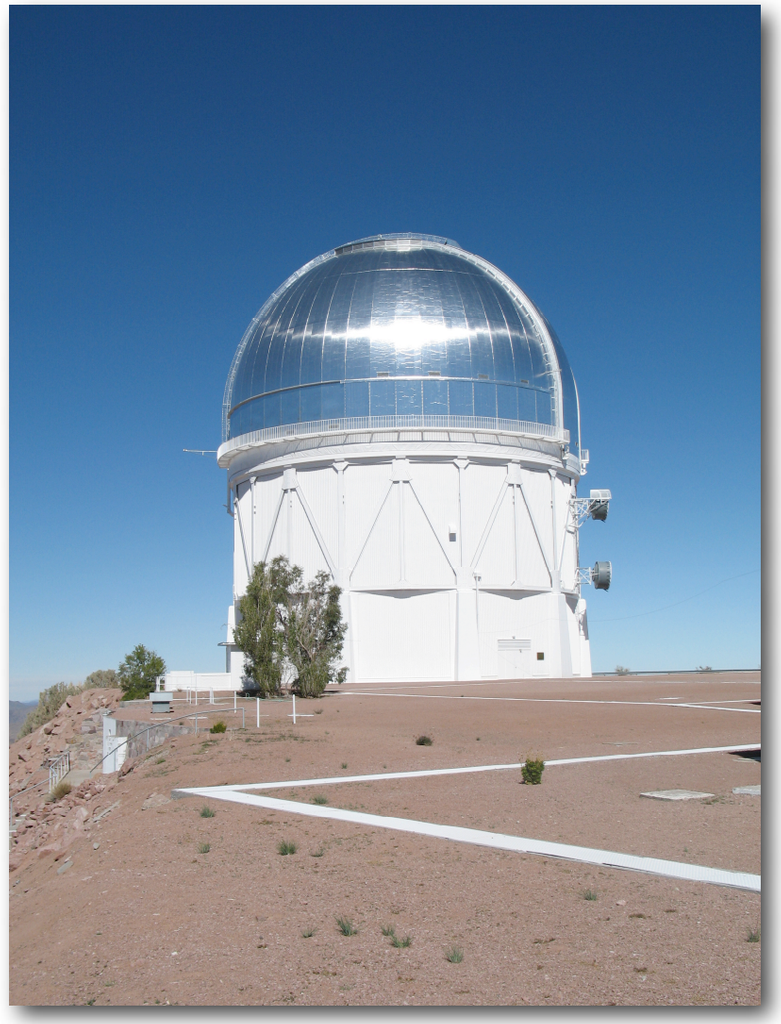
SDSS Cluster Lensing

Once the masses are known, tight constraints on cosmological parameters can be derived



Dark Energy Survey

- We can apply the same analysis in tens of equal volume samples through time
- Combining just lensing probes, constrains w to 3% statistical.
- Use supernovae and priors from other experiments (Planck) to break degeneracies
- Techniques used in the DES will translate naturally to LSST



4m Blanco Telescope
Image: David Walker